

# Critical Appraisal

### OPTIONS FOR DENTIN/ENAMEL BONDING: PART IV

Author and Associate Editor

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Four categories of resin-based dentin/enamel adhesives are currently available. These include the three-step etch-&-rinse, "one-bottle" etch-&-rinse, two-step self-etch primer systems, and "all-in-one" self-etch adhesives. In consecutive issues of the Journal, the Critical Appraisal series is presenting salient publications on research in each of the categories. This final installment of the series focuses on the all-in-one self-etch adhesives.

### IN VIVO AND IN VITRO PERMEABILITY OF ONE-STEP SELF-ETCH ADHESIVES

S. Chersoni, P. Suppa, S. Grandini, C. Goracci, F. Monticelli, C. Yiu, C. Huang, C. Prati, L. Breschi, M. Ferrari, D.H. Pashley, F.R. Tay Journal of Dental Research 2004 (83:459–64)

### ABSTRACT

**Objective:** The aim of this study was to test the hypothesis that allin-one self-etch adhesives can reduce dentin permeability in vitro and in vivo.

Materials and Methods: Three allin-one adhesives were used in the study: Adper Prompt (3M ESPE, St. Paul, MN, USA), iBond, Heraeus Kulzer (Hanau, Germany), One-up Bond F (Tokuyama, Tokyo, Japan), and Xeno III (Dentsply DeTrey, Konstanz, Germany). A two-step self-etch primer system was used as a control (Unifil Bond, GC Corporation, Tokyo, Japan).

For the in vivo portion of the study, 24 vital posterior teeth that required full crown preparations were selected. For the in vitro portion, 35 recently extracted third molars were collected. The occlusal enamel was sectioned off to expose dentin, which was polished to 180-grit to create standardized smear layers.

In vivo, teeth were prepared for crowns under local anesthetic containing 2% epinephrine. Twenty teeth were sealed using a randomly assigned adhesive. The oxygeninhibited layer was removed using cotton pellets soaked in ethanol. Polyvinylsiloxane impressions were made of the bonded teeth as well as four teeth that were prepared but not bonded. Epoxy replicas were cast from these impressions and examined with scanning electron microscopy.

In vitro, permeability was measured using a fluid conductance apparatus. For each tooth, permeability was measured at three points: (1) after acid-etching to

\*Professor and chair, Department of Operative Dentistry, University of North Carolina School of Dentistry, Chapel Hill, NC 27599-7450, USA determine its maximum baseline conductance, (2) after creation of smear layers with 180-grit abrasive paper, and (3) after dentin was sealed using an adhesive under simulated pulpal pressure.

Some of the extracted teeth were used for a second part of the in vitro study. For these, a composite resin was used as an "impression material." The dentin was bonded under simulated pulpal pressure and a composite material was applied. The specimen was placed in the dark for a few minutes to simulate the setting time of an impression material. After lightcuring the composite, the bonded specimens were sectioned and examined using transmission electron microscopy (TEM).

**Results:** Resin replicas of in vivo crown preparations revealed transudation of dentinal fluid through each of the all-in-one adhesives, although the pattern varied by material. No transudation was evident for the two-step self-etch primer system. In vitro, the presence of a smear laver reduced fluid conductance to only 12-18% of the conductance measured for acid-etched dentin. Fluid conductance of dentin bonded with the four all-in-one adhesives was similar to or greater than that of smear layer-covered dentin. One-up Bond F and iBond were less permeable than Adper Prompt and Xeno III. Fluid conductance of dentin treated with the two-step system was significantly less than smear layer-covered dentin and only about 2% of the maximum.

For the TEM analysis, specimens of Adper Prompt and Xeno III failed during sectioning, so no intact sections were available. Specimens of both One-up Bond and iBond had water blisters at the adhesive-composite interface.

**Conclusions:** The simplified adhesives tested in this study did not seal dentin well, which could have a detrimental effect on clinical performance. Because fluid movement through the polymerized adhesive layer involves slow diffusion rather than rapid movement of fluid in the dentinal tubules, their ability to reduce postoperative sensitivity should not be affected.

### COMMENTARY

This study is one of several that have reported that simplified adhesives do not seal dentin as well as more complex systems do. In this study, the permeability of a selfetch primer system was much less than that of any all-in-one system tested. The clinical implications of this permeability are not fully understood, but it is surely undesirable.

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# IN VITRO BONDING PERFORMANCE OF ALL-IN-ONE ADHESIVES. PART I—MICROTENSILE BOND STRENGTHS

J. Perdigão, G. Gomes, R. Gondo, J. Fundingsland Journal of Adhesive Dentistry 2006 (8:367-73)

#### ABSTRACT

**Objective:** The objective of this study was to determine the enamel and dentin microtensile bond

strengths ( $\mu$ TBS) of five all-in-one adhesives, with a one-bottle etchand-rinse system and a self-etch primer system used as controls. Materials and Methods: The allin-on systems tested were Adper Prompt L-Pop (3M ESPE), Clearfil S<sup>3</sup> Bond (Kuraray America, New York, NY, USA), G-Bond (GC America, Alsip, IL, USA), iBond (Heraeus Kulzer, Armonk, NY, USA), and Xeno IV (Dentsply Caulk, Milford, DE, USA). The control materials were Clearfil SE Bond (Kuraray America), a selfetch primer system, and Adper Single Bond Plus (3M ESPE), a one-bottle etch-and-rinse system.

Eighty-four extracted human molars were assigned to three groups for bond strength testing on dentin, intact enamel, and instrumented enamel. For dentin, the occlusal enamel was sectioned to expose mid-coronal dentin, which was polished to 600-grit. The adhesives were applied according to manufacturers' directions and composite crowns were built up using Filtek Z250 (3M ESPE). The bonded specimens were sectioned into sticks with a cross-sectional area of 0.7 mm<sup>2</sup>.

For intact enamel, an area of approximately  $8 \times 4$  mm was marked on the proximal surface of mandibular molars. Composite was bonded to this area using each adhesive according to its manufacturer's directions. For instrumented enamel, the same method was used except that the enamel was roughened with a coarse diamond before the adhesive systems were applied. The bonded specimens were sectioned into sticks similar to those made for dentin bond testing.

μTBS was accomplished using a universal testing machine. All pretest failures that occurred during specimen preparation were counted as having a bond strength of 0 MPa.

**Results:** Mean μTBS values ranged from 11.7 MPa to 79.1 MPa on dentin. The two control materials, Adper Single Bond Plus and Clearfil SE Bond, had the highest bond strengths and were similar to each other. In decreasing order, bond strengths were significantly less for the allin-one adhesives Adper Prompt, Xeno III, Clearfil S<sup>3</sup>, iBond, and G-Bond.

On both ground and intact enamel,  $\mu$ TBS values ranged from 9.5 MPa to 33.1 MPa. On intact enamel, four statistical groupings were identified, with Single Bond having the highest mean bond strength and G-Bond and iBond having the lowest. The results on ground enamel were similar except that Adper Prompt fell into the same statistical subset as Single Bond.

A high proportion of specimens failed before testing for some of the all-in-one adhesives. For example, nearly 50% of G-Bond specimens failed before they could be tested. **Conclusions:** The bonding efficacy of all-in-one adhesives depends on their specific composition. Given their low in vitro bond strengths and high rate of spontaneous failure, new all-in-one adhesives should be screened more strictly before they are recommended for clinical use.

#### COMMENTARY

At the time that this study was done, most of the all-in-one adhesives tested were new. Compared with the control materials, the in vitro results were very disappointing, as both dentin and enamel bond strengths were generally far less. More recent research suggests that, as a group, the all-in-one materials are improving—perhaps due not only to improvements in chemical composition but also to a better understanding of application techniques.

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# TWO-YEAR CLINICAL EVALUATION OF ONE-STEP SELF-ETCH SYSTEMS IN NONCARIOUS CERVICAL LESIONS

S. Kubo, H. Yokota, H. Yokota, Y. Hayashi *Journal of Dentistry* 2009 (37:149–55)

#### ABSTRACT

**Objective:** The purpose of this study was to evaluate the two-year clinical performance of two all-inone self-etch adhesives in restorations of noncarious cervical lesions.

Materials and Methods: This was a clinical trial involving placement of 108 cervical composite restorations in 23 patients. Ninety-three of the restorations were in noncarious cervical lesions and 15 were replacements of defective restorations. A single operator placed all of the restorations using either  $S^3$ Bond (Kuraray Medical, Tokyo, Japan) or G-Bond (GC Corporation) and a single type of hybrid composite (Note: in the USA, S<sup>3</sup> Bond is marketed as Clearfil S<sup>3</sup> Bond, pronounced as "tri-S"). A short bevel (1 mm) was placed on the enamel margin using a diamond and the dentin surfaces were roughened using a slow-speed round bur. The restorations were contoured and finished with an ultrafine diamond at the insertion appointment, but the final polishing was delayed to a later appointment.

The restorations were blindly evaluated by two examiners at 6 months and 1 and 2 years after placement. They were scored using modified United States Public Health Service criteria for retention, marginal adaptation, marginal staining, recurrent caries, other failures (e.g., color change), and gingival response. For disagreements between examiners, consensus was reached by examining 1:1 clinical photographs.

Results: Two restorations could not be examined because the teeth had been extracted for unrelated reasons: all other restorations were evaluated at each recall. At the two-year recall, only one restoration had been lost from each group and no recurrent caries was observed in either group. All restorations received "A" scores for marginal adaptation at the twoyear recall. Marginal staining was similar in both groups and increased with time. At 2 years, 21% of restorations received "B" scores, indicating marginal stain that was superficial, localized, and removable.

Conclusions: Although approximately 20% of the restorations had slight marginal staining, both all-in-one self-etch adhesives evaluated in this study demonstrated acceptable performance after 2 years of clinical service.

#### COMMENTARY

Previous in vitro studies by the same authors have shown that enamel beveling and delayed polishing can improve the marginal seal of adhesives, and both factors might have contributed to the excellent performance of the two adhesives in this clinical study. Bevels increase the area available for bonding and roughen the surface, which is known to improve the adhesion of self-etching materials.

Interestingly, the ADA's standard protocol for clinical testing of dentin adhesives calls for "no cavity preparation," and some research groups use bevels and others do not. Retention rates and marginal staining are typically worse in studies conducted by the latter. In regard to the specific results of this study, they are surprisingly good. As a group, the all-in-one adhesives tend to have lower enamel and dentin bond strengths than more complex materials. Fortunately, these simplified adhesives seem to be improving.

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# ARE ONE-STEP ADHESIVES EASIER TO USE AND BETTER PERFORMING? MULTIFACTORIAL ASSESSMENT OF CONTEMPORARY ONE-STEP SELF-ETCHING ADHESIVES

K.L. Van Landuyt, A. Mine, J. De Munck, S. Jaecques, M. Peumans, P. Lambrechts, B. Van Meerbeek *Journal of Adhesive Dentistry* 2009 (11:175–90)

### ABSTRACT

**Objective:** The purpose of this study was to determine whether all-in-one self-etch adhesives offer any benefits over multi-step adhesives for enamel and dentin bond strengths, formation of the resindentin interface, or time of application procedure.

Materials and Methods: Nine self-etch adhesives were evaluated in the study, with three of those being the two-component type that requires mixing prior to application. Clearfil SE Bond and OptiBond FL (Kerr Corporation, Orange, CA, USA) were used as controls. OptiBond FL is a three-step etch-and-rinse system.

For dentin µTBS testing, the occlusal third of extracted human molars was sectioned off to expose flat mid-coronal dentin. A standard smear layer was created using a diamond rotary instrument mounted in a special device. The same device was used to create flat buccal and lingual surfaces for enamel bond testing. All adhesives were applied according to manufacturers' directions. Composite buildups were formed, and the bonded specimens were sectioned into hourglass-shaped sticks for the  $\mu$ TBS testing.  $\mu$ TBS values were determined using a universal testing machine, and failure modes were evaluated at 50× magnification.

Resin-dentin interfaces were examined using TEM. Nanoleakage at those interfaces was evaluated by immersing the bonded specimens in a silver nitrate solution.

To evaluate the application procedure, the number of steps recommended by the manufacturer for each adhesive was counted. The total time required to complete the application procedure was calculated.

In addition, all of the one-step adhesive solutions were examined using light microscopy to examine for possible phase separation.

Results: OptiBond FL had the highest mean µTBS to enamel, at 31.6 MPa. Enamel bond strengths did not vary much by specific material, and only had a significantly lower bond strength than the others. On dentin, OptiBond FL had the highest (and statistically similar) mean µTBS values, at 38.1 MPa and 35.1 MPa, respectively. The all-in-one adhesives generally did not perform as well as the two controls on dentin. Clearfil S<sup>3</sup> Bond and Hybrid Bond (Sun Medical, Shiga, Japan) had the highest bond strengths and iBond and Absolute (Dentsply Sankin, Tokyo, Japan) had the lowest.

The morphology of resin-dentin interfaces produced by the all-inone adhesives varied greatly. Three types of hybrid layers were identified: thick (3–5  $\mu$ m) and completely demineralized with all hydroxyapatite dissolved; thinner (1.5–3.5  $\mu$ m) with a completely demineralized upper portion and a partially demineralized lower portion; and a thin (300 nm– 1.5  $\mu$ m), partially demineralized hybrid layer containing hydroxyapatite crystals. Nanoleakage was observed for all adhesives, including the controls, but varied greatly in degree and pattern of distribution. Also, droplets were observed in most of the all-in-one adhesives on both enamel and dentin within different levels of the adhesive layer.

OptiBond FL had the greatest number of steps (12) and had the longest application procedure (113 seconds). The shortest application procedure required 36 seconds. However, several of the all-in-one adhesives had as many steps and as long an application procedure as the Clearfil SE Bond self-etch control.

Three of the all-in-one adhesives were unstable after exposure to air, showing separation of phases within the solution. This was more common in the more hydrophobic adhesives, whereas osmosis-caused droplets (as described above) were more common in the more hydrophilic adhesives.

**Conclusions:** Considering bond strengths and application procedures, all-in-one adhesives are not necessarily a better alternative to multi-step adhesives.

#### COMMENTARY

The results of this study suggest that all-in-one adhesives are improving. Several of the materials tested had enamel and dentin bond strengths approaching those of a three-step etch-and-rinse and a selfetch primer control. Of course, it must be noted that these in vitro results cannot predict the longterm clinical durability of the bonds formed by the all-in-one adhesives. For example, the implications of phase separation or osmotic droplets within the adhesives are unknown. Also, the time savings achieved using some all-inone adhesives are fairly negligible. The authors state that " 'simplified' is not necessarily the same as 'improved' "—which summarizes the results of their study quite nicely.

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#### THE BOTTOM LINE

- Of the four options for resin bonding to tooth structure, the all-in-one self-etch adhesives have the shortest and least proven clinical track record.
- All-in-one adhesives do not seal dentin as well as more complex systems do.
- All-in-one adhesives bond less effectively to enamel than etch-and-rinse adhesives do, particularly if the enamel has not been instrumented in any way.
- All-in-one adhesives bond less effectively to dentin than two-step, self-etch primer systems do.
- As measured in the laboratory, and to a lesser extent in clinical trials, the performance of all-in-one adhesives appears to be improving as newer materials are developed.

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